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Impacts of a comprehensive public engagement training and support program on scientists' outreach attitudes and practices

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ABSTRACT

Scientists are increasingly being called upon to play a more prominent role in the interface of science and society by contributing to science literacy in ways that support two-way exchanges with the public. However, many remain reluctant to participate in public engagement activities in part because they feel they lack relevant skills and experience. We surveyed scientists trained on engagement through a nationwide program called Portal to the Public and examined how participation in the program may have influenced their self-efficacy, commitment and attitudes about outreach, and perceived benefits from conducting outreach based on two-way exchange with lay audiences. Participating scientists who responded to the survey reported being deeply involved in and highly committed to hands-on interactive public outreach, felt their engagement skills had improved, and even viewed benefits of their engagement training that extended into university teaching and career development. Our findings suggest a comprehensive engagement training model, which incorporates learning theory, helps scientists build their own outreach strategies, provides opportunities to practice, and offers easy access to audiences, can have a sustained impact on disposition, perceived skills, and type of outreach conducted by scientists interested in deeper engagement with the public.

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Introduction

Since a late 1990s call by a large group of eminent scientists to expand 'good science' practice to include 'informing the general public and, especially, taxpayers' (Bazzaz et al., 1998, p. 879), disseminating research findings to increase scientific literacy has grown commonplace within the scientific enterprise, particularly through unidirectional activities, such as developing education materials and giving presentations (e.g. Bazzaz et al., 1998; Pace et al., 2010; Skrip, 2015). However, scientists are increasingly being challenged to broaden their science literacy contribution to support two-way exchanges with the public (Agre & Leshner, 2010; Bauer & Jensen, 2011; Skrip, 2015). Both the National Academy of Sciences and American Association for the Advancement of Science (AAAS) have taken up this call for more effective science communication practice (Lohwater & Storksdieck, 2017).

The AAAS defines 'public engagement with science' as 'intentional, meaningful interactions that provide opportunities for mutual learning between scientists and members of the public' (Braha, 2015, p. 18). Using this or similar terms, many researchers have highlighted the value of expanding science communication to include this concept of public interfaces that allow firsthand and intimate

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two-way exchanges between scientists and non-scientists (Bauer, Allum, & Miller, 2007; Grand, Davies, Holliman, & Adams, 2015; Groffman et al., 2010; McCallie et al., 2009; Selvakumar & Storksdieck, 2013; Wiehe, Kaiser, Durant, Levenson, & Linett, 2014). However, while many scientists may now be active in science communication, their efforts do not typically include two-way exchange strategies (Besley & Tanner, 2011; Yuan et al., 2017), suggesting they remain rooted in traditional formats such as public lectures and media interviews. Training on communication and engagement offers a conduit to connect scientists to communication research and its application (Besley, Dudo, Yuan, & Abi Ghannam, 2016; Dudo, 2013; Miller, Fahy, & Team, 2009; Trench & Miller, 2012). But while leaders of such programs recognize this opportunity, their training rarely includes guidance and support on fostering productive dialogues with broader audiences (Yuan et al., 2017).

If such training and follow-up support existed, would this change how scientists approach public engagement with science? To explore this question, we examined the impact of a comprehensive public-engagement training program, *Portal to the Public*, on self-efficacy, commitment and attitudes of scientists who participated through 45 museums, science centers and universities across the U.S. In brief, our findings suggest comprehensive training, which incorporates learning theory, helps scientists build their own outreach strategies, provides opportunities to practice, and offers easy access to audiences, can have a sustained impact on disposition, perceived skills, and type of outreach conducted by scientists interested in deeper engagement with the public.

Literature review

Types and benefits of public engagement with science

Public engagement can include fairly new forms of communication (Storksdieck, Stylinski, & Bailey, 2016). For example, citizen science may provide an in-depth engagement experience, as least for some participants (Martin, 2017). With many U.S. adults receiving their news online, public engagement by scientists can include forums like Reddit and Facebook (McClain, 2017), as social media promotes two-way exchanges and empowers non-scientists to be 'co-producers of knowledge, rather than consumers of content' (Miah, 2017, p. 39). Public engagement can push the boundary of science communication when scientists seek intersections between their interests and values and those of untraditional or underrepresented public groups, such as collaborations between ecologists and fashion designers (Nadkarni & Levey, 2017). But meaningful dialogue can also be integrated into more traditional venues, such as public lectures, tours, and media exchanges, by incorporating questions that promote discussion and other tactics (Storksdieck et al., 2016). A good example of these more traditional opportunities is 'meet-a-scientist' events at museums, which have been shown to build connections, find common ground, and deepen understanding (Woods-Townsend et al., 2016). Regardless of the venue, science engagement approaches might include storytelling, humor, mystery, integration into everyday life, artistic expression, and more (Wiehe et al., 2014).

Two-way symmetrical communication between scientists and the public has the potential to do more than simply disseminate the latest scientific findings and established science principles, and indeed can benefit both parties. Many reports and articles have highlighted the broader benefits (e.g. Bauer et al., 2007; Lohwater & Storksdieck, 2017; McCallie et al., 2009; McComas & Besley, 2011), which can include improving attitudes about scientists, the scientific enterprise, and its role in society, and building trust and legitimacy of science to inform decision-making. Additionally, it can inform scientists about the public's perception and perspectives on science, and enhance relationships and build mutual understanding.

Barriers to adopting public engagement strategies

Several hurdles must be scaled for broad adoption of public engagement. Many scientific societies, organizations and universities offer science communication training, but most center on transmission of knowledge and do not build understanding of how people learn (Besley & Tanner, 2011; Besley, Dudo, & Storksdieck, 2015); they also do not distinguish differences in venues such as a media exchange versus a public tour (Baram-Tsabari & Lewenstein, 2017), and, as noted, lack support on using two-way exchange tactics (Yuan et al., 2017). There are a few exceptions such as the European Science Communication Network (Miller et al., 2009), AAAS Center for Public Engagement with Science and Technology training and resources (https://www.aaas.org/pes), National Academies' Science Ambassadors Program (https://scienceambassadors.org), the Astronomy Ambassadors program (Fraknoi et al., 2014) and the Portal to the Public Network operated out of Pacific Science Center in Seattle, WA. Adding to the challenge of adopting public engagement are low levels of institutional support for scientists involvement in public engagement. Burchell, Sheppard, and Chambers (2017) refer to this integration in institutional cultures as a 'work in progress' in the U.K. due to ongoing pressure and rewards associated with research and teaching. U.S. scientists have also reported lacking time for public engagement due to these pressures (Ecklund, James, & Lincoln, 2012).

An additional hurdle that is particularly vexing is scientists' lingering attachment to the so-called 'deficit model' of communication (Bauer et al., 2007; Sturgis & Allum, 2004; Suldovsky, 2016). This model assumes the public has an information deficit (Gross, 1994) and that ignorance explains the lack of public support and action (Groffman et al., 2010). As described by Gross (1994), practitioners of the deficit perspective do not try to persuade or build trust, assuming its passive audience already values and trusts science. Instead, they envision audiences as empty vessels to fill with critical scientific information and facts through a one-way transmission (experts to learners). Besley and Tanner (2011) found scientists believe the public is ill-informed about science topics and issues for various reasons including being irrational, emotional, fear-prone, self-interested and stubborn. From this perspective, it makes sense that improvements in practice focus on ways to simplify presentations (Cook, Pieri, & Robbins, 2004) or make them more entertaining (Davies, 2008).

From this deficit model viewpoint, an informed public would shift attitudes and behaviors to support the scientific enterprise (Logan, 2001) – a seemingly possible domino effect from knowledge to attitudes to behaviors. However, the deficit model does not align with what is known about how people learn. Audiences do not receive science information in a vacuum; they bring prior experiences, understanding, beliefs, values, motivations and interests, which shape their expectations, attention, interpretation and assimilation of messages (National Academies of Sciences Engineering Medicine, 2016a; National Research Council, 2009). Furthermore, evidence suggests that greater knowledge does not necessarily lead to change in attitudes about science issues; instead, other factors, such as perception of shared values, trustworthiness and media use, play a larger role (e.g. National Academies of Sciences Engineering Medicine, 2016a).

Using an example of a comprehensive public engagement training model

Public engagement training needs a multi-faceted approach to address these barriers. In order to pursue realistic goals and align outreach activities accordingly, scientists need opportunities to deepen their understanding of how people learn; guidance on tactics for more interactive communication; opportunities to practice, reflect and refine; and platforms or interfaces that make it easier to reach audiences. As with any professional development experience, follow-up support is often key to successful and sustained action (National Academies of Sciences Engineering Medicine, 2016b). This may include encouragement and even enticements from scientists' home institutions, funding sources, and disciplinary fields overall, all elements that nudge behavior towards a desired state (Kollmuss & Agyeman, 2002).

For this study, we focused on one mature public engagement training model, Portal to the Public (PoP), because its validated framework centers on enhancing scientists' two-way exchanges to support targeted learning outcomes and, as a national effort, involves a relatively large number of scientists (upwards of 750 by 2017). Led by Pacific Science Center (Seattle, Washington) and funded by the NSF and Institute of Museum and Library Services, the more than 10-year-old PoP program seeks to connect public audiences with the research and innovation that occurs in their own communities through activities and dialogue with local scientists. Originally focused on science centers, the PoP Network has expanded to include training of scientists through zoos, aquariums, botanical gardens, and university groups – currently, over 60 organizations across North America. PoP is founded on the premise that scientists should engage directly with audiences, often through interactive hands-on activities and using an understanding of how people learn and how to engage audiences in discovery-based learning (Selvakumar & Storksdieck, 2013). As a part of the professional development training, scientists are guided in identifying key messages and audience takeaways, and potential points of personal relevance for various public audiences. Most organizations using the PoP framework have scientists create activities that align with these messages and often take the form of a hands-on, tabletop manipulative based on their research. Example training activities include reflecting on each scientists' 'expert blind spot' (i.e. forgetting what it is like to be a non-expert) and on the pleasure of discovery through exploration rather than simply being told; practicing strategies to spark initial conversations and support dialogue through effective questioning strategies; creating concept maps to consider various frames for conversations with public audiences; and developing and prototyping specific material elements for their dialogue-based outreach activity. Each participating organization adapts the PoP framework to fit its context and goals but common to all is the creation of opportunities for scientists to use their dialogue-rich activities during public events, and an explicit expectation that scientists engage with the public (i.e. this is an integral part of the training).

We used the PoP framework and members of the Network as an example of a well-established public engagement with science training and ongoing support system (Montano, 2013; Tisdal, 2011). With this example, we asked the following research questions:

(1) What are objectives of scientists who are participating in public engagement training?
(2) What impact does public engagement training have on these scientists' attitudes, self-efficacy and commitment?
(3) Do scientists believe impacts extend beyond public engagement activities?

Methods

Instrument construction

An online questionnaire was developed for scientists who have participated in PoP training; we included one item on reasons for outreach adapted from a national survey of scientist outreach motivation and practices (Dudo & Besley, 2016). It consisted of open and closed-ended questions; items were chosen or developed *de novo* based on pre-determined concepts linked to the hypothesized outcomes of the project. The questionnaire was iterated with PoP lead staff at the Pacific Science Center to guarantee appropriateness of items, pilot-tested, revised, and implemented on Qualtrics, an established online survey tool.

Sampling and sample description

PoP Network staff at Pacific Science Center identified local staff at 45 member sites within the PoP Network and invited them to distribute a link to the online questionnaires to current and former scientist participants using standardized language. The questionnaire remained open from mid-August to mid-October 2016 with one reminder sent within this period. Two hundred and ninety-nine respondents started the survey. Sample sizes for each question varied because of the dynamic nature of online sampling (forking) and respondents were allowed to skip questions.

Respondents represented 25 of the 45 queried institutions. Most institutions had 1 to 21 respondents with the exception of two institutions, which had double or more than other institutions –

Pacific Science Center in Seattle WA (founding institution) and Oregon Museum of Science and Industry in Portland OR (a very active program). Based on an estimated 750–1000 participating scientists, our response rate is 30–40%. We do not know if lack of response is due to systematic bias or random patterns. To be conservative in our interpretation, we assume our resulting sample represents a best-case scenario of scientists with mostly positive program experience and positive dispositions to the program's underlying conceptual framework and design.

Respondents were slightly skewed towards women (58%), and many worked at research universities (68%) followed by government entities, teaching universities, non-profits and industry, all with less than 10% representation (Table 1). A majority of respondents were emerging professionals such as graduate students and postdocs (71%) with just 20% mid-career professionals and 9% senior professionals in their field (which is representative of the typical distribution of PoP participants). As post-docs and graduate students vary in their responsibilities beyond conducting research and taking classes, it is not surprising that only about two in five have no teaching, training or outreach responsibilities in their current position.

Data analysis and limitations

The study's underlying 'best-case scenario' assumption prevents inferring from our sample to the larger population of scientists or outreach support systems. As such, our analysis is limited to descriptive statistics, which answer only what was possible under the specific conditions of the program we studied. Consequently, constructed answers were analyzed using iteratively derived codes, which were then used to extract major trends from the data. We did not attempt to quantify most of the constructed answers since the nature of the questions was to reveal conceptual categories (how respondents thought), and analysis was focused on identifying typical answers (rather than how many of the respondents thought in a particular way). While the results of the study are limited to the specific case, we nonetheless argue that similar results are possible under equally similar conditions.

Results

Pop scientists engage for multiple altruistic reasons

When PoP scientists were asked to prioritize learning objectives for public engagement, they assigned the highest priority to 'getting people excited about science' and to 'making science findings relevant' (Table 2). These items scored one rating point or higher than in a similar survey (with same

Table 1. Gender, status and institutions of scientist in this study ($N = 218–264$).

	Percentage of PoP scientist respondents
Gender	
Female	58%
Male	42%
Status level	
Graduate students and post-doc	71%
Mid-career	20%
Senior professional	9%
Institution of participating scientists	
Research University	68%
Government	7%
Teaching University	6%
Non-Profit/NGO	5%
Industry	4%
Medical Field	2%
Self employed	2%
Liberal Arts College	1%
Other	5%

range from 1 to 7) conducted with members of the American Association for the Advancement of Science (AAAS) by Dudo and Besley (2016). Also, important to scientists was 'ensuring culture values science,' 'encouraging younger people [children, young adults, girls, minorities] to pursue science careers,' and 'getting the public to appreciate the role of science and be informed on scientific issues.' Somewhat less important but related were correcting misinformation, supporting decision-making, and demonstrating links between science and society (i.e. science advances society's well-being and scientists share community values). Lowest rated on the list were the statements 'ensure findings are included in public debate' and 'listening to others about scientific issues,' although both still rated at more than average importance, indicating that scientists in our study recognize these motivations as potentially valuable and relevant.

Pop scientists commit to engagement

Scientists trained through PoP exhibited very high engagement overall and often participated in multiple forms of public engagement (Table 3). Almost all respondents stated they conducted hands-on activities with manipulatives, providing clear evidence that the comprehensive PoP program achieved its public engagement goal. Other formats with considerable audience interaction were also popular. After removing two outliers with very high outreach rates, participating scientists reported conducting on average 4.3 outreach events at their partner institutions and 4.1 events elsewhere over the average two years since the training (not shown).

Just over half of respondents stated that they conduct public engagement activities at a higher frequency now than *before* they started participating in PoP (Table 4). The small decline would be expected simply from changes in scientists' professional contexts (i.e. fewer affordances for conducting public engagement activities). While higher frequency of engagement is not surprising given the PoP training and subsequent logistical and organizational support for conducting outreach activities, almost all stated that the *quality* of their public engagement improved since their initial PoP training, and none felt that the quality declined. This perceived improvement was achieved despite a potential ceiling effect for responding scientists who might have been inclined to participate in engagement (given our assumption of a best-case scenario of respondents). Furthermore, half of the respondents plan to increase the frequency of their public engagement activities in the future, and almost all of the remainder indicated that they would maintain current levels of engagement. Of course, this type of

Table 2. Mean priority rating of various public engagement objectives public for scientist respondents in this study ($N = 285–286$) and for Dudo and Besley (2016). Any differences in survey items are provided by text in parentheses.

	Mean of respondents from this study	Mean from Dudo and Besley (2016)
Getting people excited about science (exciting others about science)	6.6	5.6
Describing scientific findings in ways that make them relevant to people (framing or shaping messages to resonated with people's existing views)	6.3	5.0
Ensuring that our culture values sciences	6.2	–
Getting people to appreciate the role of science in their daily lives	6.2	–
Encouraging more children and young adults to pursue science as a career	6.2	–
Ensuring that people are informed about scientific issues (informing, i.e. educating, others about science)	6.2	5.9
Encouraging girls and minorities to pursue science as a career	6.1	–
Correcting scientific misinformation (defending science from perceived misinformation)	5.8	6.0
Helping people use science to make better decisions	5.8	–
Demonstrating that science advances society's wellbeing	5.8	–
Demonstrating that scientists share the values of their community	5.6	–
Ensuring that scientists' findings are part of the public debate	5.4	
Hearing what others think about scientific issues	5.2	–

Notes: The item read, 'How much are each of the objectives below a priority for you when you engage the public. The rating varies from "very low priority' (1) to 'average prority' (4) to 'very high priority' (7)'.

Table 3. Percentage of scientist respondents involved in various public engagement activities (*N* = 277).

	Percentage of respondents
Hands-on activity in which audience directly manipulates objects	94%
Lecture or discussion with considerable audience Q&A or other audience interaction	60%
Demonstration in which audience observes but does not directly manipulate objectives	59%
Tour (e.g. lab tour, nature walk, or a planetarium presentation)	50%
Collaborating on science research with the public (e.g. citizen science)	19%
Other	3%

Notes: The item, read 'Which of the following type(s) of public engagement activities have you ever conducted or actively taken part in at museums or any other venues (e.g. science pub, open house event, science festival.'

declared behavior intention, particularly when positive response bias can be expected (e.g. to please the questioner or oneself), is only a rough proxy for actual future behavior. However, the validity of the behavior intention embedded in the questions was supported by open-responses such as this one:

> After completing the Science Communication program, I went back to my university and helped to create "Open House" events where researchers bring the public into our department and show them cool animals, talk about research, etc. This would not have been feasible without the training I received at my PoP institution.

When preparing and implementing public engagement activities, scientists face a variety of 'tensions' that need to be balanced. Generally speaking, PoP scientists prefer a smaller audience for outreach events so they can go deeper in terms of content and experience (Table 5). While they show a slight preference for sharing their ideas, they lean towards interactive dialogue and strive for striking a balance between theirs and the audience's agenda. Respondents rated themselves high on all core strategies for conducting effective public engagement activities (mean scores between 4.1 and 4.5 on the converted 5-point scale, Table 6). With an average rating of 4.4 (on a 5-point scale), participating scientists confirmed the value of the initial training for their current perceived level of pedagogical abilities and skills (Table 7). Despite these generally high self-reported rating on engagement strategies, when asked to rate whether they planned to improve their engagement practices in the future through reflection on current practice or participation in ongoing training (using a 10-point from 1 ('definitely no') to 10 ('definitely yes'), 43% chose the highest score (10), and 83% selected a score of 8 or higher (not shown), indicating an awareness of the need for ongoing growth and development.

We asked scientists to share an example or personal story that illustrates how participating in their public engagement training might have influenced them. As anticipated, there were many statements about personal growth around communication skills and strategies, as this comment indicates,

Table 4. Percentage of scientist respondents reporting on frequency, quality and future plans of their public engagement activities (*N* = 268–274).

	Percentage of respondents
'I am currently conducting public engagement activities at [*options listed below*] frequency than before my PoP training.'	
A higher	53%
The same	40%
A lower	7%
'The way I currently conduct public engagement has [*options listed below*] since my public education training'	
Improved	90%
Remained the same	10%
Worsened	0%
'In the future, I plan to [*options listed below*] of my public engagement activities.'	
Increase the frequency	52%
Maintain at same frequency	46%
Decrease the frequency	2%

Table 5. Percentage of scientist respondents' reporting how they balance competing pedagogical practices when preparing for public engagement.

Item	1	2	3	4	5	6	7	8	9	10	Mean	N	Item
Large*	2	2	8	10	11	28	47	**69**	41	14	7.3	232	Small*
Shallow Extensive**	2	3	7	16	27	46	59	**60**	23	18	6.8	261	Deep Limited**
Sharing†	3	8	14	**47**	30	45	31	15	6	2	5.4	201	Hearing†
Engaging††	10	24	44	**52**	23	17	32	11	1	3	4.5	217	Presenting††
Audience Agenda†††	4	16	37	39	29	30	**56**	20	3	1	5.2	235	My Agenda†††

Notes: The item read, 'When you conduct public engagement activities, you are faced with various tensions that you might consider in your preparations. Use the [provided] slider bar to indicate where you place the greater emphasis when you are preparing for public engagement. Please note that the numbers do not indicate any particular value judgement.' The scale ranged from 1 (practice listed in the first column of the table) to 10 (practices listed in the last column of the table).

**Shallow audience engagement but extensive content covered (1) to Deep audience engagement, but limited content covered (10).

*Large audience but no one-on-one interaction (1) to Small audience and extensive one-on-one interaction (10).

†Sharing your perspective (1) to Hearing other's perspectives (10).

††Engaging in dialogue (1) to Presenting ideas (10).

†††Focusing on audience agenda (1) to Focusing on my agenda.

> I have a new appreciation of the first few sentences of a conversation. The invitation to participate. The sharing of something about myself, and the vice versa. The exchange of names. This is a skill that I will use for much more than just science outreach.

Others described memorable encounters, which made the respondents think deeply about their work or the relationship between science and the public, as the following example illustrates:

> A little girl at a fruit & veggie botany dissection ran up to me to get a carrot because she was so excited about the science of plants. Her parents said she had never been so enthusiastic about anything before and they were planning to get her some botany books afterwards. As I continue to progress through my PhD program, I find a lot of my colleagues have given up on the general public - they feel as though people are just too stupid to understand science or logic. But having regular exposure to the public, I can attest that people *want* to learn and grow - they are just confronted by a Wild West of misinformation to navigate with very little training on how to discern the quality of information sources. I don't think I would see the roots of our systemic education failings without the PoP program tools, and without understanding the problem, you can never solve it.

Impacts extend beyond outreach

Participating scientists also reported that the training changed their ability to position their academic research and, to a lesser extent, how they communicate their work to colleagues and to decision

Table 6. Mean rating for scientist respondents' self-reported pedagogical abilities and skills.

	Mean agreement of this impact ($N = 271$)	Mean agreement of PoP training on this impact ($N = 267–268$)
My understanding of how people learn enables me to do effective public outreach	4.5	4.4
I can effectively explain my work or area of study to non-experts	4.4	4.3
I can effectively adjust my communication for learners of different ages or experience levels	4.3	4.5
I can effectively use dialogue-based interactions with the public to explore science concepts	4.2	4.4
I have a good understanding of the nature of learning in informal environments	4.1	4.4

Notes: The item read, 'Rate the degree to which the following five statements are true for you in column 1, and in column 2 rate the degree to which PoP training from your partnering institution might have impacted you in those five abilities and skills.' The first column read, 'Rate statements from −2 (strongly disagree) to +2 (strongly agree),' and the second column read, 'Rate statements from −2 (no impact on me) to +2 (high impact on me)'. To calculate the means, responses were converted to a positive scale from 1 strongly disagree or no impact) to 5 (strongly agree or high impact).

Table 7. Mean rating of changes in various professional practices of scientist respondents.

	Mean $N = 262–264$	Percentage n/a
Placing your research in a broader context	3.8	3%
Communicating your work to colleagues	3.5	2%
Communicating your work to decision makers	3.4	16%
Mentoring and advising students	3.3	15%
University teaching	3.2	35%
Mentoring and advising staff	2.7	48%
Staff training	2.7	48%
Conducting research	2.3	10%
Conducting administrative, management or other key job duties	2.3	28%

Notes: The item read, 'To what degree have each of the following professional practices changed due to your PoP training. The rating varies from "no change' (1) to 'large change' (5).' Also provided is the percentage who select 'n/a' (not applicable).

makers, and how they conduct university mentoring and teaching (Table 7). Scientists did not report that participation in PoP training improved their research – an average score of 2.3 on a 5-point scale should probably be considered negligible. These trends were reiterated in open-response questions. Scientists noted improvements in teaching and mentoring, as indicated by this quote:

> After this training, I realized that I often just dictate tasks to [the undergrads that I teach], rather than try to get them to really understand what they are doing. I've made more of an effort to make them become actively involved in our protocols, rather than just following a list of instructions.

These communication skills have extended to other professional audiences, such as dissertation committee members, scientists from other disciplines, decision makers, and landowners. The transfer of skills to these broader audiences is demonstrated in the following quote:

> The interactions that I have with small groups of people at the science museum are a perfect practice ground for the variety of conversations that I could have with decision makers. Many of the best practices (for example, making it a two-way conversation) apply equally well to a conversation with a decision maker.

Although not common in our sample, there were, nonetheless, some descriptions of how the impact of the training extended to participants' science research, helping them reflect on its role in broader contexts, as suggested below:

> Participating in [PoP training program] has impacted how I explain my research to the public, as well as how I communicate in transdisciplinary research groups, and how I write grant proposals. It has helped me frame my research in the context of the world's grand challenges of water, energy, food, and health, and helped me improve my research questions and design based on public feedback and communicated needs.

Others suggested increased motivation for their research, as indicated by this quote.

> It has helped me feel part of my community. This, for me, was the biggest impact, and a very important one. As a researcher, I often feel very isolated in the lab, and that my work will only have an impact in the long run. By adding outreach to my work, I can also know I am making an impact in the short term as well.

Some responses indicated that participation in PoP and with public engagement directly contributed to career expansion and even career changes including apply for a science policy fellowship, seeking jobs that 'value science communication skills and opportunities' and a 'mov[e] away from isolated applied research settings,' and starting a new job developing museum programing and exhibit content.

Discussion

We explored the impacts of a comprehensive public engagement training on scientists' attitudes, skills and behavior. Our example, Portal to the Public, centers on building relationships between educators and scientists, introducing scientists to learning theory and engagement tactics, providing opportunities to practice, and ensuring easy access to audiences. Our findings demonstrate that, when trained and supported in public engagement strategies and activities, scientists are willing and committed to participate in two-way exchanges with the public. That is, almost all responding PoP scientists reported they pursued hands-on engagement activities using manipulative objects (see Table 3), and conducted some type of outreach an average of four times per year. While this high level of implementation was sought and thus expected in the Portal to the Public training program, few other programmatic contexts currently foster this level of public engagement. One recent example that has similar features is a U.K. intervention, which applied a mix of training, practice at live events, and support (including peer mentoring), and also saw high rates of implementation among engineering professionals (Fogg-Rogers, Lewis, & Edmonds, 2017).

The PoP program approach aligns with multiple learning goals of a conceptually coherent definition of science communication learning, as developed by Baram-Tsabari and Lewenstein (2017). Specifically, the program directly targeted learning goals associated with content knowledge (e.g. building understanding of how people learn), methods (e.g. guiding scientist through questioning strategies), participation (providing venues to practice and implement engagement activities, which the authors note is often missing from science communication training), and identity (enhancing scientists' self-efficacy and embracing them as contributors to museum experiences). Survey responses, provided in various table and quotes, also offers evidence of self-reflection and affective characteristics (excitement, interest, and motivation). These last two goals may be influenced by self-selection of PoP respondents, and may be more critical in a successful engagement training that targets scientists with more diverse viewpoints.

Aligning with a large body of research on behavior change (e.g. reviews in (Heimlich & Ardoin, 2008), engagement training needs to be coupled with support structures that simultaneously encourage a desired behavior and lower barriers for engaging in this behavior. For example, Besley, Oh, and Nisbet (2013) found that scientists' attitudes about perceived ease of, and capacity for engagement predict their willingness and their reported engagement levels.

Not all of the PoP scientists' outreach activities centered around dialogue with public audiences, nor should this be a requirement or expectation (see Table 3). For instances, public lectures can be effective and attract large audiences. But scientists participating in the PoP program clearly indicated a preference for deeper, small-group engagements along with a willingness to balance their and their audiences' agendas, as well as dialogues and presentations (see Table 5). While we cannot prove causation within our example program, we can nonetheless reasonably attribute the degree of engagement-based outreach and the degree to which individuals conducted this outreach to the PoP training and subsequent support, since both were predicted by the program's underlying theoretical framework (Selvakumar & Storksdieck, 2013).

Beyond training, numerous factors can impact scientists' engagement including self-efficacy, autonomy, attitudes, scientific status, presumed media influences, and norms (e.g. Dudo & Besley, 2016). Applying theories of planned behavior and procedural justice Besley et al. (2015) suggest that if scientists have positive attitudes about public engagement, believe their peers also hold positive views (norms), and feel their public engagement will result in a positive impact (high self-efficacy), they are more likely to begin and continue to be involved in such activities. Poliakoff and Webb (2007) also show the importance of attitudes, efficacy and norms, along with prior experience, in driving future intent to participate in public engagement. While we did not explore PoP scientists' attitudes about public engagement, we do have evidence of high levels of self-efficacy associated with basic learning theory and dialogue-based interactions with public audiences (also an elicit goal of the training) (see Table 6 and quotes). Furthermore, in addition to their current outreach, most PoP scientists indicated that they will continue conducting engagement activities in the future (see Table 4 and quotes), and that they have an appreciation for continued learning and reflection on practice (more than 80%). Our results reiterate the importance of scientists' beliefs about their communication abilities in promoting their involvement in public engagement. It aligns with Robertson Evia, Peterman, Cloyd, and Besley (2017), who developed a scale for self-efficacy because, as they argued, it is a critical measure of scientists' public engagement. Subsequent studies are needed to understand actual changes in the quality of their communication efforts.

Most PoP participants and survey respondents are emerging science professionals (graduate students and post-docs, see Table 1) who may expect that time for outreach activities will decrease as their careers advance, yet they stated a current and sustained commitment to public engagement. This trend contrasts with Dudo (2013) who reported that higher status level (i.e. more senior level and more career publications), along with other characteristics, was a key factor contributing to public communication activity. Likewise, Bauer and Jensen (2011) and Besley et al. (2013) found those who were senior or mid-career were more likely to participate in public engagement. Alternatively, Fogg-Rogers et al. (2017) also had success supporting early career engineering professionals and highlighted the importance of mentoring and peer support networks, which were also part of PoP programs as participants typically completed their training in cohorts. While our study cannot be used to describe potential impacts on scientists based on status or other attributes, it suggests comprehensive professional development is key to recruitment and retention of young scientists. In fact, the strong participation of emerging scientists provides hope for a slow cultural shift in future cohorts of scientists with regard to the need for and value of direct engagement with the public; that is, a change in identity of what it means to be a scientist (Baram-Tsabari & Lewenstein, 2017). It also signals a slow shift in the perception of graduate and postgraduate training in general. The U.S. National Institutes of Health and the U.S. National Science Foundation are both investing into experimental programs to enhance graduate education by providing additional skills beyond those associated with increased disciplinary expertise. Foundational to all of these programs are communication and engagement skills, and the PoP program may be emblematic of the kind of supplemental educational and practical experiences that future science researchers will require and expect.

We also examined objectives that PoP scientists assign to their outreach (i.e. outcomes for themselves and for their audiences). Our findings indicate that the comprehensive training at the base of the PoP experience may predispose participating scientists to have a broader view of communication objectives compared with the general population of scientists in the U.S. (Dudo & Besley, 2016). That is, while objectives associated with building knowledge remain important, PoP scientists placed greater emphasis on generating excitement and framing issues to make them relevant for audiences; they also ranked listening to others at above average importance (see Table 2). These broader targets align with effective informal education practice (National Research Council, 2009) and constructivist theories of learning (National Research Council, 1999), and reflect the inclusion of learning theory and framing in the PoP professional development.

While others have emphasized the importance of messaging that resonates with audiences (e.g. Nisbet & Scheufele, 2009), there is evidence that many scientists are unaware or even resistant to framing. For example, in their survey of AAAS members, Besley et al. (2015) found some scientists see framing as manipulative or strategic rather than informative and objective. Indeed, respondents in that survey gave the lowest value and lowest ethical rating to 'framing science in ways that would resonate with audiences.' Additionally, they gave lower value to goals that help audiences view scientists as responsive, caring and concerned. However, as Gross (1994) pointed out, 'scientists are engaged in the process of persuasion in all of their professional and intellectual activities, not only in the forum, but also in the laboratory, the field, and the study' (p. 3). More recently, Donner (2014) reiterated this, noting even the choice of a research subject is a form of advocacy. Kotcher, Myers, Vraga, Stenhouse, and Maibach (2017) found no change in public credibility of scientists who were advocating about climate change, demonstrating that scientists may be more uncomfortable about participating in advocacy than they need be, given that the public may expect more scientist engagement in public discourse (Donner, 2017). Donner emphasizes that public engagement with science can be 'compromised by this pernicious false notion of a binary choice between science and advocacy' (p. 431).

Besley et al. (2016) discovered that many training programs focus on teaching communication skills to participating scientists, but fail to help them articulate communication objectives that could be achieved through these skills. When they do focus on objectives, these are typically limited to enhancing knowledge and do not include others such as building trust, fostering excitement, and framing scientific issues. They made the case that, given desired objectives of their communication efforts, scientists need to pursue a strategic model of communication rather than a journalist model; that is, they should start their efforts by articulating objectives, and ideally (measurable) objectives, and then align the engagement activity with those objectives. Although the PoP program provided scientists with a common learning objective (connecting audiences to local research and innovation), its staff did help scientists align their individual engagement activities with this objective. This may explain why PoP scientists in our sample exhibited somewhat different priorities for their outreach activities (see Table 2) than those that emerged in various national surveys of scientists (e.g. Besley et al., 2015; Besley et al., 2016).

Finally, while moderate in degree, PoP scientists nonetheless indicated that the benefits of participating in PoP extended to other aspects of their professional work. They felt moderate improvement in communicating and positioning their work with diverse audiences – colleagues, students, decision-makers and staff (see Table 7 and quotes). This is not surprising as learner-centered education, with opportunities for discovery, dialogue and reflection, are part of effective pedagogical practices regardless of the setting (National Research Council, 2009, 2012a, 2012b), and thus the PoP program helps prepare these scientists to be better educators in the classroom and beyond. Our finding also aligns with Baram-Tsabari and Lewenstein (2017) who emphasized that communication training should promote self-reflection that supports '… placing one's story in the greater picture and making it relevant to societal concerns' (p. 294).

Some scientists may also be able to transfer abilities and skills gained through PoP into their research environment, and indeed few respondents expressed greater motivation to pursue laboratory- and field-based research. In some cases, participation in PoP might have even contributed to changes in career trajectories. We do not know if some of the career-change respondents participated in PoP because of an existing desire to make a switch, or whether PoP created the impetus for this career change. The distinction is somewhat irrelevant though, since PoP clearly provided a platform through which the respondents were able to nurture a new career identity. Others have also highlighted various personal and professional rewards for scientists engaging with the public – beyond improved communication and pedagogical skills. For example, Pace et al. (2010) cited learning through discussion and constructive argumentation, exposure to new applications of current research or new ideas for future research, can improve job fulfillment and potential recognition from funders, colleagues and the public. There is even the possibility of higher levels of scientific publishing and academic rank for those who engage in thoughtful public engagement activities, as has been observed for scientists with popular publications (Bentley & Kyvik, 2011), though this would be a question for further study. But this study is the first to demonstrate the potential for broader impacts beyond the quality of outreach efforts among scientists who participate in a comprehensive public engagement training and support program.

Study limitation

A key limitation of our study is the potential for strong selection bias into the program itself and into the sample of respondents, the predominance of early-career professionals amongst program participants, and the reliance on a self-reported survey instrument. Clearly, possible self-selection bias into the program and equivalent response bias to the questionnaire requires us to be careful in concluding that the underlying program model for training and ongoing support would scale to a large pool of scientists. That is, we do not know how many scientists, given opportunity to participate in PoP-like programs, would engage and whether outcomes, like the ones described here, would endure. However, while we need to assume that our findings describe a 'best case scenario,' we nonetheless have ample evidence that the program model itself of initial in-depth research-based training, development of engagement objectives and strategies as a capstone to the training, and subsequent ongoing logistical and motivational support contributed to the growth of participating scientists.

Conclusion

Our study highlights the benefits and the need for public engagement training, and for associated opportunities for subsequent two-way exchanges, echoing the call of others for greater participation of scientists in local public forums (e.g. Groffman et al., 2010). Should expectations for engagement-style outreach extend beyond scientists with strong positive dispositions, additional program elements that enhance self-efficacy (e.g. self-reflection) and reinforce the overall purpose of public engagement with science may need to be more explicitly addressed.

In addition to studies of quality of these exchanges and aligning with Besley et al. (2013), future efforts should address scientists' resistance to engagement strategies and gain institutional support to shift culture and norms associated with public engagement within academia. A recent NSF spin-off of the PoP program will specifically explore institutional partnerships between science museums and universities, and consider changes necessary for a more systematic approach of public engagement efforts among graduate students, staff and faculty. This and related efforts will also need to address the lack of formal evaluation of public engagement efforts (Grand et al., 2015). As suggested by Neresini and Bucchi (2011), ultimately performance indicators and standards may be necessary to encourage research institutions to consider public engagement and societal dialogue as an essential element of 'good science.' But we caution that higher demands on the quality and quantity of outreach efforts by scientists require core institutional support, and that enhancing individual scientists' ability and skills in conducting high quality public engagement activities should become an integral part of the preparation for scientific careers. Given the preponderance of early-career PoP participants, this could include public engagement training in doctoral programs, coupled with practice through service learning.

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References

Agre, P., & Leshner, A. I. (2010). Bridging science and society. *Science*, *327*(5968), 921–921.

Baram-Tsabari, A., & Lewenstein, B. V. (2017). Science communication training: What are we trying to teach? *International Journal of Science Education, Part B*, *7*(3), 285–300.

Bauer, M. W., Allum, N., & Miller, S. (2007). What can we learn from 25 years of PUS survey research? Liberating and expanding the agenda. *Public Understanding of Science*, *16*(1), 79–95.

Bauer, M. W., & Jensen, P. (2011). The mobilization of scientists for public engagement. *Public Understanding of Science*, *20*(1), 3–11.

Bazzaz, F., Ceballos, G., Davis, M., Dirzo, R., Ehrlich, P. R., Eisner, T., … Matson, P. A. (1998). Ecological science and the human predicament. *Science*, *282*(5390), 879–879.
Bentley, P., & Kyvik, S. (2011). Academic staff and public communication: A survey of popular science publishing across 13 countries. *Public Understanding of Science*, *20*(1), 48–63.
Besley, J. C., Dudo, A., & Storksdieck, M. (2015). Scientists' views about communication training. *Journal of Research in Science Teaching*, *52*(2), 199–220.
Besley, J. C., Dudo, A. D., Yuan, S., & Abi Ghannam, N. (2016). Qualitative interviews with science communication trainers about communication objectives and goals. *Science Communication*, *38*(3), 356–381.
Besley, J. C., Oh, S.-H., & Nisbet, M. (2013). Predicting scientists' participation in public life. *Public Understanding of Science*, *22*(8), 971–987.
Besley, J. C., & Tanner, A. H. (2011). What science communication scholars think about training scientists to communicate. *Science Communication*, *33*(2), 239–263.
Braha, J. (2015). *AAAS communicating science program: Reflections on evaluation*. AGU Fall Meeting Abstracts.
Burchell, K., Sheppard, C., & Chambers, J. (2017). A 'work in progress'?: UK researchers and participation in public engagement. *Research for All*, *1*(1), 198–224.
Cook, G., Pieri, E., & Robbins, P. T. (2004). 'The scientists think and the public feels': Expert perceptions of the discourse of GM food. *Discourse & Society*, *15*(4), 433–449.
Davies, S. R. (2008). Constructing communication: Talking to scientists about talking to the public. *Science Communication*, *29*(4), 413–434.
Donner, S. D. (2014). Finding your place on the science – advocacy continuum: An editorial essay. *Climatic Change*, *124*(1-2), 1–8.
Donner, S. D. (2017). Risk and responsibility in public engagement by climate scientists: Reconsidering advocacy during the trump Era. *Environmental Communication*, *11*(3), 430–433.
Dudo, A. (2013). Toward a model of scientists' public communication activity: The case of biomedical researchers. *Science Communication*, *35*(4), 476–501.
Dudo, A., & Besley, J. C. (2016). Scientists' prioritization of communication objectives for public engagement. *PloS one*, *11*(2), e0148867.
Ecklund, E. H., James, S. A., & Lincoln, A. E. (2012). How academic biologists and physicists view science outreach. *PloS one*, *7*(5), e36240.
Fogg-Rogers, L., Lewis, F., & Edmonds, J. (2017). Paired peer learning through engineering education outreach. *European Journal of Engineering Education*, *42*(1), 75–90.
Fraknoi, A., Fienberg, R. T., Gurton, S., Schmitt, A. H., Schatz, D., & Prather, E. E. (2014). Training Young Astronomers in EPO: An Update on the AAS Astronomy Ambassadors Program. In Manning James G., Hemenway Mary Kay, Jensen Joseph B., & Gibbs Michael G. (Eds.), *Ensuring Stem Literacy: A National Conference on STEM Education and Public Outreach* (Vol. 483, pp. 415). San Francisco: Astronomical Society of the Pacific.
Grand, A., Davies, G., Holliman, R., & Adams, A. (2015). Mapping public engagement with research in a UK university. *PloS One*, *10*(4), e0121874.
Groffman, P. M., Stylinski, C., Nisbet, M. C., Duarte, C. M., Jordan, R., Burgin, A., … Coloso, J. (2010). Restarting the conversation: Challenges at the interface between ecology and society. *Frontiers in Ecology and the Environment*, *8* (6), 284–291.
Gross, A. G. (1994). The roles of rhetoric in the public understanding of science. *Public Understanding of Science*, *3*(1), 3–23.
Heimlich, J. E., & Ardoin, N. M. (2008). Understanding behavior to understand behavior change: A literature review. *Environmental Education Research*, *14*(3), 215–237.
Kollmuss, A., & Agyeman, J. (2002). Mind the gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? *Environmental Education Research*, *8*(3), 239–260.
Kotcher, J. E., Myers, T. A., Vraga, E. K., Stenhouse, N., & Maibach, E. W. (2017). Does engagement in advocacy hurt the credibility of scientists? Results from a randomized national survey experiment. *Environmental Communication*, *11*(3), 415–429.
Logan, R. A. (2001). Science mass communication: Its conceptual history. *Science Communication*, *23*(2), 135–163.
Lohwater, T., & Storksdieck, M. (2017). Science communication at scientific institutions. In K. H. Jameison, D. Kahan, & D. A. Scheufele (Eds.), *The Oxford Handbook of the Science of Science Communication* (pp. 179–186). New York, NY: Oxford University Press.
Martin, V. Y. (2017). Citizen science as a means for increasing public engagement in science: Presumption or possibility? *Science Communication*, *39*(2), 142–168.
McCallie, E., Bell, L., Lohwater, T., Falk, J. H., Lehr, J. L., Lewenstein, B. V., … Wiehe, B. (2009). *Many experts, many audiences: Public engagement with science and informal science education*. Washington, DC. Retrieved from http://www.informalscience.org/sites/default/files/PublicEngagementwithScience.pdf
McClain, C. R. (2017). Practices and promises of Facebook for science outreach: Becoming a "nerd of trust". *PLoS Biology*, *15*(6), e2002020.

McComas, K. A., & Besley, J. C. (2011). Fairness and nanotechnology concern. *Risk Analysis*, *31*(11), 1749–1761.

Miah, A. (2017). Nanoethics, science communication, and a fourth model for public engagement. *NanoEthics*, *11*(2), 139–152.

Miller, S., Fahy, D., & Team, E. (2009). Can science communication workshops train scientists for reflexive public engagement? The ESConet experience. *Science Communication*, *31*(1), 116–126.

Montano, P. A. (2013). Changed perceptions about science communication: A case study of STEM graduate students in portal to the public (Doctoral dissertation).

Nadkarni, N., & Levey, D. (2017). Ecology on the runway: Engaging the public in unexpected places. *The Bulletin of the Ecological Society of America*, *98*(2), 103–109.

National Academies of Sciences, Engineering and Medicine. (2016a). *Science literacy: Concepts, contexts, and consequences*. Washington, DC: The National Academies Press.

National Academies of Sciences, Engineering and Medicine. (2016b). *Science teachers' learning: Enhancing opportunities, creating supportive contexts*. Washington, DC: National Academies Press.

National Research Council. (1999). *How people learn: Bridging research and practice*. Washington, DC: National Academies Press.

National Research Council. (2009). *Learning science in informal environments: People, places, and pursuits*. Washington, DC: The National Academies Press.

National Research Council. (2012a). *Discipline-Based education research: Understanding and improving learning in undergraduate science and engineering*. Washington, DC: The National Academies Press.

National Research Council. (2012b). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: The National Academies Press.

Neresini, F., & Bucchi, M. (2011). Which indicators for the new public engagement activities? An exploratory study of European research institutions. *Public Understanding of Science*, *20*(1), 64–79.

Nisbet, M. C., & Scheufele, D. A. (2009). What's next for science communication? Promising directions and lingering distractions. *American Journal of Botany*, *96*(10), 1767–1778.

Pace, M. L., Hampton, S. E., Limburg, K. E., Bennett, E. M., Cook, E. M., Davis, A. E., … Likens, G. E. (2010). Communicating with the public: Opportunities and rewards for individual ecologists. *Frontiers in Ecology and the Environment*, *8*(6), 292–298.

Poliakoff, E., & Webb, T. L. (2007). What factors predict scientists' intentions to participate in public engagement of science activities? *Science Communication*, *29*(2), 242–263.

Robertson Evia, J., Peterman, K., Cloyd, E., & Besley, J. (2017). Validating a scale that measures scientists' self-efficacy for public engagement with science. *International Journal of Science Education, Part B*, *8*(1), 40–52.

Selvakumar, M., & Storksdieck, M. (2013). Portal to the public: Museum educators collaborating with scientists to engage museum visitors with current science. *Curator: The Museum Journal*, *56*(1), 69–78.

Skrip, M. M. (2015). Crafting and evaluating broader impact activities: A theory-based guide for scientists. *Frontiers in Ecology and the Environment*, *13*(5), 273–279.

Storksdieck, M., Stylinski, C., & Bailey, D. (2016). *Typology for public engagement with science: A conceptual framework for public engagement involving scientists*. Corvallis, OR. Retrieved from http://informalscience.org/typology-public-engagement-science-conceptual-framework

Sturgis, P., & Allum, N. (2004). Science in society: Re-evaluating the deficit model of public attitudes. *Public Understanding of Science*, *13*(1), 55–74.

Suldovsky, B. (2016). In science communication, why does the idea of the public deficit always return? Exploring key influences. *Public Understanding of Science*, *25*(4), 415–426.

Tisdal, C. (2011). *Portal to the Public summative evaluation: Comparative case studies of implementation at five sites*. St. Louis, MO: Tisdal Consulting.

Trench, B., & Miller, S. (2012). Policies and practices in supporting scientists' public communication through training. *Science and Public Policy*, *39*(6), 722–731.

Wiehe, B., Kaiser, D., Durant, J., Levenson, T., & Linett, P. (2014). *The evolving culture of science engagement*. Retrieved from http://www.cultureofscienceengagement.net/2013convening/report/

Woods-Townsend, K., Christodoulou, A., Rietdijk, W., Byrne, J., Griffiths, J. B., & Grace, M. M. (2016). Meet the scientist: The value of short interactions between scientists and students. *International Journal of Science Education, Part B*, *6*(1), 89–113.

Yuan, S., Oshita, T., AbiGhannam, N., Dudo, A., Besley, J. C., & Koh, H. E. (2017). Two-way communication between scientists and the public: A view from science communication trainers in North America. *International Journal of Science Education, Part B*, *7*(4), 341–355.